Duke University School of Medicine

Doctor of Physical Therapy

The Effect of Fatigue on Neuromuscular Risk Factors for Knee Injury: A Systematic Review

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Background

- 2.5 million athletes report to the emergency room each year with a knee injury, representing one of the most commonly injured joints.[1]
- Fatigue can have a significant effect on injury; however, the effect of fatigue on these risk factors is largely unknown (see **Figure 2**).
- Risk factors for injury during sport can be divided into two separate categories:
  - Internal risk factors: physical deficiencies, physical fitness, previous injury, psychological factors, physical build, age & sex.
  - External risk factors: type of sport, venue, equipment, weather conditions, and other athletes.[2]
- In an effort to prevent the fatigue-related knee injuries, we must establish the effect fatigue has on neuromuscular risk factors, including electromyographic activity (EMG) of knee musculature, postural stability, and proprioception (see **Figure 3**).

Purpose

- To examine the evidence that fatigue affects neuromuscular risk factors for knee injury including electromyographic activity (EMG) of the knee musculature, postural stability, and proprioception.

Methods

- Systematic review: Pubmed, Embase, and CINAHL
- Highlighted inclusion criteria:
  - (1) Healthy active individuals ages 17-39 years
  - (2) Measurable fatigue as an intervention pre and post fatigue protocol (see **Figure 1)**
  - (3) Outcomes measured post-fatigue protocol: electromyography, postural stability, and proprioception
- Highlighted exclusion criteria:
  - (1) Previous lower limb reconstruction or any injury occurring in previous six months
  - (2) Outcomes including: joint kinematics, ground reaction forces, joint kinetics, or strength

Figure 1: Inclusion Criteria for Fatigue Protocol Assessment

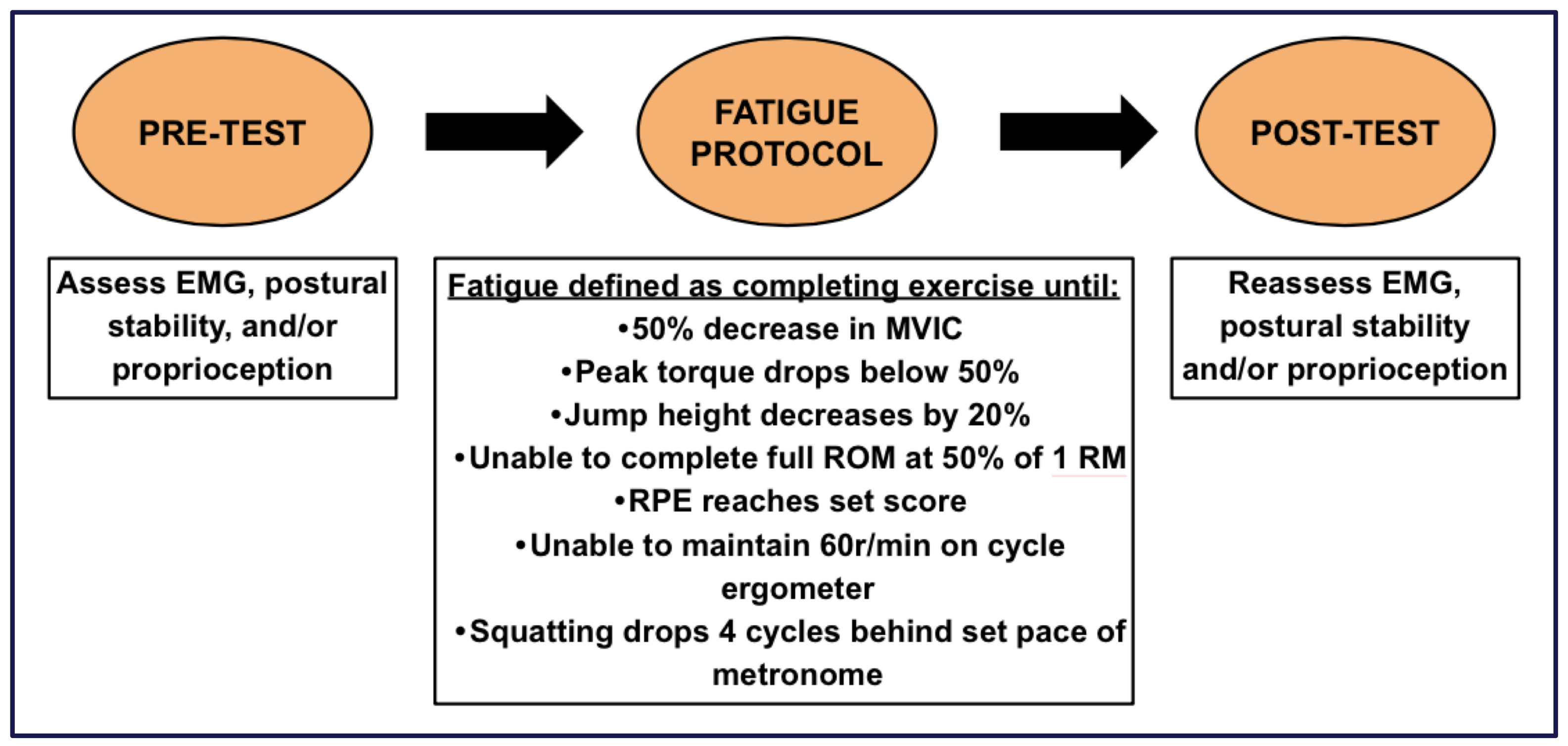
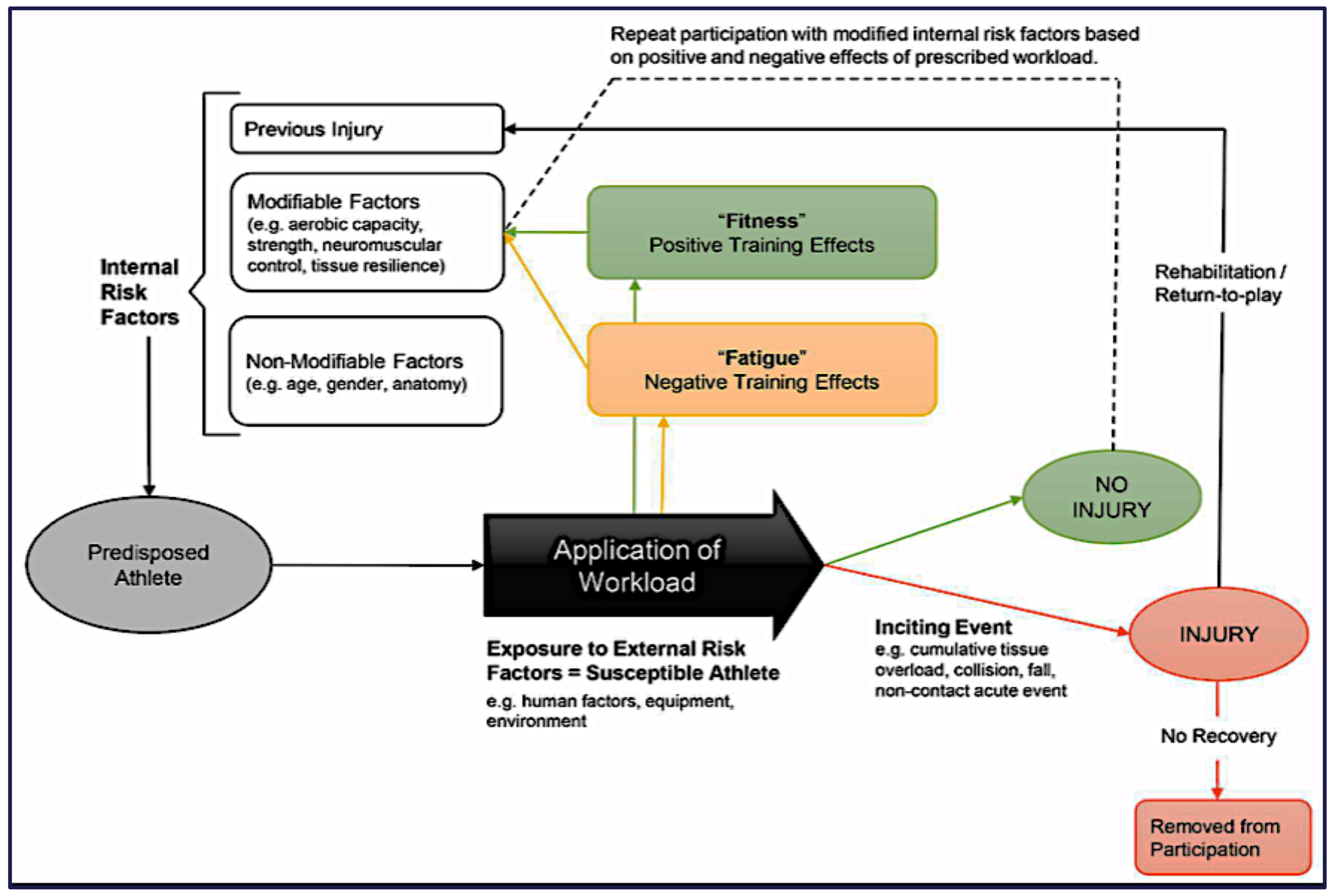


Figure 2: Workload—Injury Aetiology Model (from Windt and Gabbett, 2016)



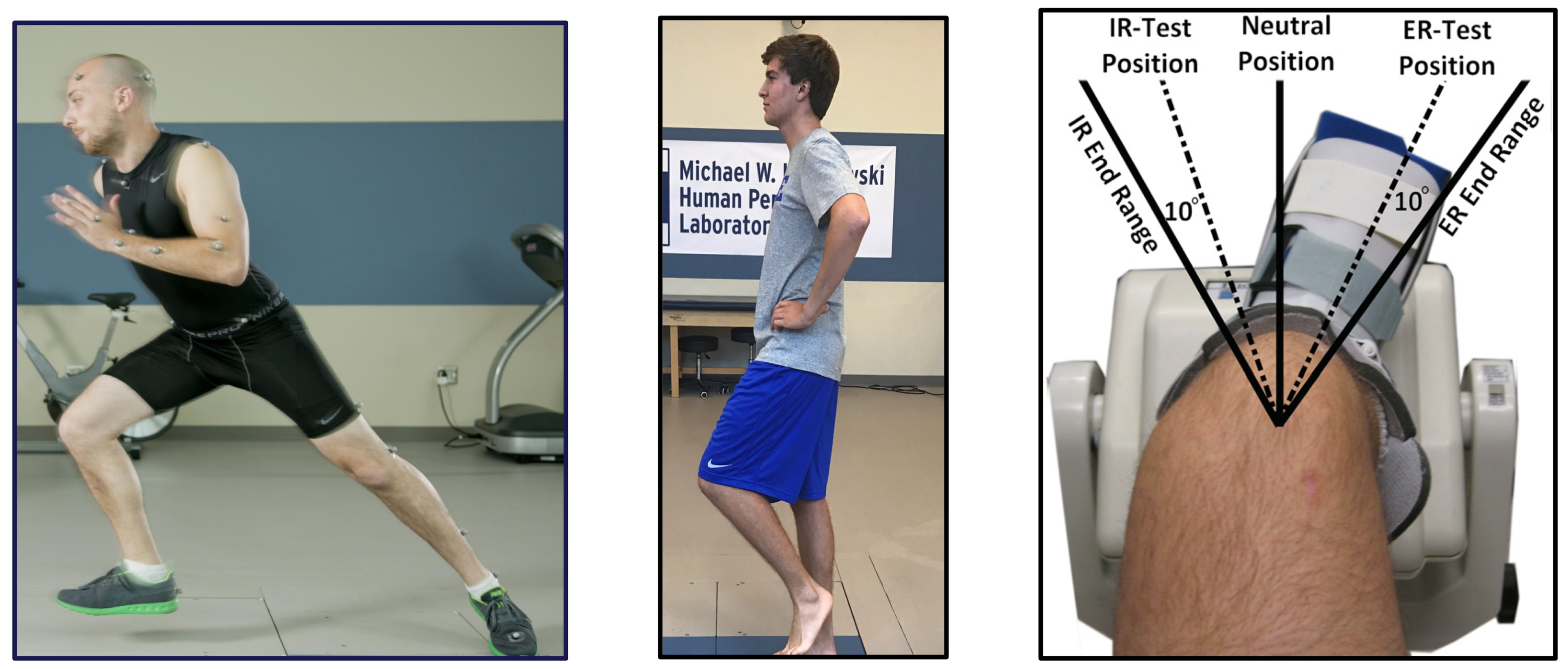
Results

Neuromuscular Risk Factor Studied	Outcome Measure	Articles	Significant Results Post Fatigue
Muscle Activation	EMG during Jumping/Landing	Gehring et al. 2009; Kellis, Kouvelioti, 2009; Kim et al. 2015; Padua et al. 2006; Patrek et al. 2011; Smith et al. 2009;	• Delay in gluteus medius activation • Decreased hamstring & anterior tibialis activation, increased gastrocnemius & soleus activation, & increased quadricep/hamstring coactivation, w/ greater effect in females • Activation of lateral thigh muscles prior to medial thigh muscles, leading to increase in knee joint abduction in females
	EMG during Gait	Ballantyne et al. 2010; Kellis, Liassou, 2009; Kellis et al. 2011	• Decreased tibialis anterior activity, increased vastus lateralis activity, decreased hamstring activity during IC and stance, & decreased gluteus maximus activation • Increased vastus medialis & biceps femoris activation during treadmill running
	EMG during Eccentric Contraction	Longpre et al. 2015	• Increased vastus lateralis & rectus femoris activation in lunges as compared to squats • Coactivation was not altered
Postural Stability	Static & Dynamic Balance Recovery	Dickin et al. 2008; Johnston et al. 1998; Mademli et al. 2008; Whyte, 2015;	• Balance impairments in both AP and ML directions • Decreased balance skill and star balance test performance in both women & men
	Center of Foot Pressure	Arora et al. 2016; Bizid et al. 2009; Bruniera et al. 2013; Paillard et al. 2014	• Decreased peak force • Increased mean COP • Decreased postural stability when both unilateral & bilateral knee extensors were fatigued
	COP excursion velocity	Gribble et al. 2004	• Greater COPV in ML direction
Proprioception	Threshold to Detect Passive Motion (TTDPM)	Allison et al. 2016; Rozzi et al. 1999; Skinner et al. 1986	• Decreased detection of joint motion in extension
	Joint Position Sense	Changela et al. 2013; Gear, 2011	• Reproduction error noted in perception of joint position
	Absolute Angular Error	Lattanzio et al. 1997; Miura et al. 2004	• Increased absolute angle error after all fatigue protocols

Conclusion

- Fatigue has a profound impact on EMG activity, proprioception, and postural stability in the lower extremity, increasing the risk of knee injury in physically active individuals during fatigue related situations.

Figure 3: Variables Examined (EMG, Postural Stability, and Proprioception)



Clinical Relevance

- The examination of risk factors for musculoskeletal injury is an essential step in injury prevention.
- The evidence outlined in this systematic review demonstrates how fatigue negatively affects neuromuscular characteristics – potentially providing insight for interventions that target fatigue.
- Possible prevention strategies include:
  - Physical training programs that attempt to reduce the effects of fatigue on risk factors for injury
  - Nutritional interventions
  - Sleep, rest, and other activities designed for recovery
- Future research is necessary to examine these interventions.

Acknowledgements / References

1. Gage, B. E., et al. (2012). "Epidemiology of 6.6 million knee injuries presenting to United States emergency departments from 1999 through 2008." *Acad Emerg Med* 19(4): 378-385.
2. van Mechelen, W., et al. (1992). "Incidence, severity, aetiology and prevention of sports injuries. A review of concepts." *Sports Med* 14(2): 82-99.
3. Windt, J. and T. J. Gabbett (2017). "How do training and competition workloads relate to injury? The workload-injury aetiology model." *Br J Sports Med* 51(5): 428-435.
4. Photos courtesy of Dr. Timothy Sell
5. Photo credit: https://amp.businessinsider.com/images/50eacecbecad041114000022-750-562.jpg